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Effect of ferrite overlays on the characteristics of $\lambda/2$ rejection filter

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Abstract : Ferrite materials in pellet-form, in general, tend to increase the attenuation of the circuit. The study of thickness variation from thin film range → thick film → paste → pellet is being undertaken to get a better insight into the behaviour of ferrite material at microwave frequencies. The thickness of the overlay for optimum performance is expected to be composition dependent and grain size dependent. Usually, ferrites are used as substrates in nonreciprocal microwave devices. If ferrites of suitable composition and thickness are used as overlay and/or underlay, it is felt that by proper magnetisation, non reciprocal devices can be designed on alumina substrates.

Keywords : Rejection filter, microwave frequency, reciprocal devices.

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It has been reported [1–4] that overlay structures can be used to improve component performance. Ferrite elements play a very important role in the full exploitation of microwave integrated circuits. In this paper, the effect of various types of ferrites and non-magnetised Fe_2O_3 in pellet-form on the properties of microstripline $\lambda/2$ rejection filter is reported. The non-magnetised Fe_2O_3 is also studied because in all the ferrites used, Fe_2O_3 is the major constituent.

A $\lambda/2$ open circuited rejection filter resonant at 9.5 GHz has been designed and fabricated using standard curves and tables [5]. Alumina substrate of dimension 0.025" × 1" × 1" was metallized upto 5 μm thickness with Cr/copper using the standard procedure of vacuum evaporation-electroplating-photolithography. Transmission measurement of the filter are taken in the x-band (8–12 GHz). The quality factor Q was calculated from the formula $Q = f_0/\Delta f$ where ΔF is the 3 db bandwidth of filter. The bulk overlays was in pellet form of diameter 1 cm and 0.27 cm thick. Six type of ferrites prepared by standard ceramic technique and non-magnetised Fe_2O_3 were used. The ferrites used are F_1–mg ferrite, F_2–Cu Cd ferrite, F_3–ZnCo ferrite, F_4–Mg Mn Zn Al ferrite, F_5–Cu Ge ferrite, F_6–Ni ferrite. The dimensions of these pellets were such that they covered the entire coupling area as shown in Figure 1.

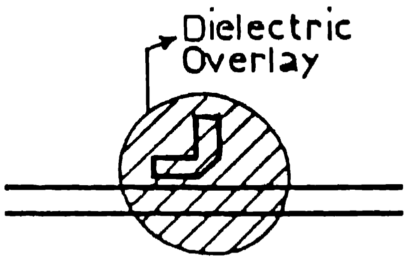

Figure 1. $\lambda/2$ rejection filter (Cr–Cu) with overlay on coupling region

The plot of frequency (GHz) *vs* rejection (db) is given in Figure 2(a), (b), (c), (d) for the various overlays. The values of rejection frequency, rejection ratio, bandwidth, Q and tan

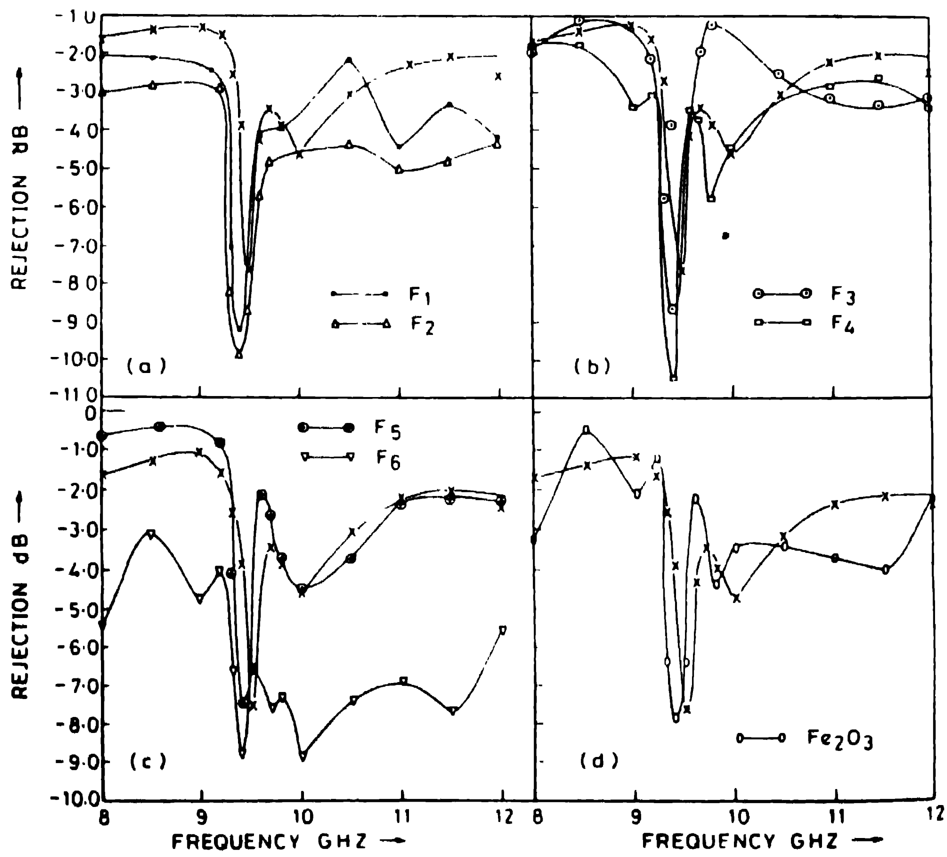

Figure 2. Graph of frequency (GHz) *versus* rejection (db) X–X–X–without overlay.

δ of the filter without and with overlay is tabulated in Table 1. From Figure 2 it is seen that for all the overlays, there is a shift in the resonant frequency from 9.5 GHz (without overlay)

Table 1. Characteristics of $\lambda/2$ rejection filters without and with overlay.

Sl. No.	Type of overlay	f_0 GHz	Rejection ratio db	Bandwidth MHz	Q	$1/Q$ tan δ
1	without overlay	9.5	-7.65	130	73.07	0.014
2	F_1–Mg ferrite	9.4	-9.50	200	47 00	0.021
3	F_2–CuCd ferrite	9 4	-9 90	290	32.40	0.031
4	F_3–ZnCo ferrite	9.4	-8.70	200	47 00	0.021
5	F_4–Al, Mn, Mg, Zn ferrite	9.4	-10.50	150	62.66	0.016
6	F_5–CuGe ferrite	No definite Resonance	Overall high rejection	–	could not be found	–
7	F_6–Ni ferrite	9.4	-7.55	180	52.22	0.019
8	F_7–non magnetised Fe_2O_3	9.4	-7.85	250	37.60	0.026

to 9.4 GHz. This shift is constant irrespective of the type of ferrite used and also for non-magnetised Fe_2O_3. All the ferrites except F_6 show an increase in the rejection ratio, for F_6 there is a decrease as compared to without overlay case (Table 1). Fe_2O_3 overlay shows only slight increase (–7.65 db→ –7.85 db). From the Figure 2 it is also seen that in general, the attenuation has increased at all frequencies due to the ferrite overlays. An interesting result is that with F_5 (Cu Ge ferrite) the filter looses its characteristics and above 9.4 GHz shows very high attenuation. F_4 (Mg Mn Zn Al ferrite) shows the maximum rejection of –10.5 db. There is a general tendency of oscillatory behaviour above 10 GHz, whereas for lower frequencies below 9 GHz the behaviour is similar to without overlay condition with enhanced attenuation. Due to overlay the 3 db bandwidth has increased with corresponding decrease in Q (Table 1). Different ferrites show different degrees of variation. The effective loss tangent tan $\delta = 1/Q$ has increased due to all ferrite overlays, maximum increase being for F_2 (Cu–Cd ferrite).

From the results it is evident that there is 100 MHz reduction in resonant frequency (f_0) for the ferrites investigated. The decrease in f_0 is due to the increase in the effective dielectric constant of the system. The physical length of the resonator being the same without and with overlay, the increase in ε_{eff} with overlay, will cause the frequency to decrease for the same length of resonator. The dielectric overlay replaces the air by the dielectric material and makes the fringe field pass through the dielectric changing the fringing capacitance and gap capacitance and causing changes in the resonant frequency. The dielectric constant of alumina substrate is 9.6 and that of the ferrites used, lie in the range of 9.6–12 and dielectric constant of Fe_2O_3 is 14.2. The effective dielectric constant due to ferrite overlay is ~ 6.759 and for Fe_2O_3 is ~ 8.915 compared to ε_{eff} of 6.077 without overlay. Since the ε_{eff} of Fe_2O_3 overlayed structure is more than the others one expects the shift in frequency to be more than others. It has been reported [3] that overlays of different dielectric constant, shifts the frequency by different amounts. One would expect larger changes in f_0 due Fe_2O_3 overlay as compared to other ferrites whose dielectric constants lie around 10.2.

The overlay thicknesses are of the order of 4 times the thickness of substrate, the fringing field in the dielectric medium (overlay) does not come back to the substrate whereby increasing the losses, due to which attenuation might be increasing. The high attenuation beyond 9.4 GHz for Cu.Ge ferrite and loss of filter characteristics might be due to the presence of some higher modes like surface waves. More detailed study is needed to find the reason behind this phenomenon, F_4 seems to be more suited for microwave purposes. Holst and Lemke [6] have also used similar ferrites for microwave purposes. Since these ferrites are basically oxides it is felt that by suitable composition and thickness, the microwave properties can be tailored for specific purpose microwave integrated circuits.

From the above study it is seen that ferrite materials in pellet-form, in general, tend to increase the attenuation of the circuit. The study of thickness variation from thin film range → thick film → paste → pellet is being undertaken to get a better insight into the behaviour of ferrite material at microwave frequencies. The thickness of the overlay for optimum performance is expected to be composition dependent and grain size dependent. Usually, ferrites are used as substrates in non-reciprocal microwave devices. If ferrites of suitable composition and thickness are used as overlay and/or underlay it is felt that by proper magnetisation non-reciprocal devices can be designed on alumina substrates.

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